LCA Methodology

Applying an Heuristic Approach to LCA

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Abstract

Practical analysability of Life Cycle Assessment is high related to data availability and data quality. High costs and many efforts are required for performing traditional high data-quality LCA. An heuristic approach for data collection can provide more useful results than other approaches using quantitative data which already demonstrate errors or improperness which have been recognised. The heuristic approach provides data both cheaply and rapidly which is not surely exact but still accurate enough for practical situations. Although the heuristic approach has some restrictions in comparison to other alternatives, it is a valuable option.

Keywords: Accuracy; cost; empirical research; expert, decision making; heuristic approach, data availability; heuristic approach, data quality; heuristic approach; heuristics; LCA, practical analysability; transportation; uncertainty

1 Introduction

Every societal entity performs LCAs with different purposes which have interactions with one another. LCA has two meanings for any organisation, especially for the profit organisations. On the one hand, LCA is an important activity for buyer requests and several regulations. For example, even though the organisations do not like the implementation of LCA because of cost, time, and exposure of confidential data, they have no choice if the buyers from foreign countries require the certification of ISO 14000. On the other hand, it can be one of the competitive weapons which differentiates their products or images from that of their competitors. PORTER (1980) described differentiation as being one of the generic competitive strategies for an organisation. Meanwhile, detailed methodologies for achieving differentiation are not considered. How can this be achieved? One of the useful ways is quantification which plays a role in increasing persuasiveness in many cases. It solves some possible conflicts and arguments that can occurr by qualitative, inaccurate expressions. For example, expressions such as environmental soundness are followed by questions like:

- How to decide whether a product or a service is environmentally sound?
- How sound is it?
- What is the threshold of the soundness?

LCA is one of the answers for this problem. Especially inventory analysis can be used as persuasive solutions for the first two questions, and the last solutions are provided with impact assessment.

However, it is hard to consider LCA as the ultimate solution because it also has methodological problems such as data credibility. Moreover, so many efforts are required for collecting and preparing data. A couple of simplified methods have been developed which attempt to reduce the cost and time.

In this paper, shortcomings of traditional LCA and typical, simplified LCA are described briefly, and a conceptual heuristic approach for acquiring quantitative data with a qualitative method is introduced and evaluated. Practical application of the developed methods or their results is not intended here.

2 Difficulties and Shortcomings of Traditional LCA

Through all the phases of LCA, even during critical review, there is a gap of original objective according to the purpose and scope defined, and availability of practical situations. Practical analysability is deeply related with data availability and data quality.

2.1 Data availability restrictions

Some of the problems pertinent to data restrictions are:
1. Available data is not prepared if the organisation has not intended to implement LCA.

2. Information supply is restricted because of security if the LCA practitioner and target organisation are not the same.

3. Nevertheless, internal data is prepared, while data of the upper or lower production chain would not be handled in the same manner.

Data availability can be more serious because the organisations which try to perform LCA nowadays are located in the upper production chain (such as oil refineries, chemical industries and the federal government, etc.). For small companies, it is more difficult to carry out an LCA with their capabilities. So it is hard to analyse a life cycle of a production chain.

2.2 Data quality restrictions

Data from one course of research cannot be applied easily to other cases. It is described in traditional LCA methodologies that each condition which is assumed and premised on the data must be satisfied fully. Many studies use a linear approach for estimating values of emissions or impacts, while the real situations do not show this linearity (→ Fig. 1)
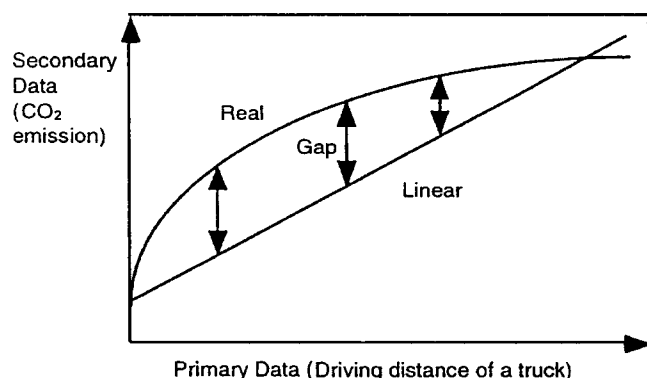

Fig. 1: Gap between linear data set and real data

Almost all problems in the goal and scope definition stage seem to be solved by changing the definition of system boundaries. However, when the scope is changed, the applicability of the LCA results is naturally restricted at the same time. To reduce the gap, the primary goal and scope or accuracy of data must somehow be adjusted according to the real conditions.

3 An Alternative – Simplified LCA

Simplified LCA, which has many different options, is an alternative that considers the reduction of cost and efforts explicitly. The word 'simplified' is an aggregative one that includes the meaning of screening, streamlining, and any other approaches which try to simplify the full LCA. Screening and streamlining LCA is the representative in the current research stream. They are very well known and need not be described in detail.

Screening LCA is conducted to determine whether an additional study is needed and where the focus of this implementation should be. It can be accomplished through a variety of methods, including streamlined LCA approaches and methods (WEITZ et al., 1996). However, the objective of implementation is limited in internal applications. If the scope is changed due to data gaps or cost and efforts, it means that there is a possibility of deviating from the basic objective of the performance.

The typical form of streamlining LCA has difficulties in deciding total environmental burden because it considers selective processes which are assessed as critical during the whole life cycle. Although an organisation can reduce cost and efforts in data gathering with this approach, it will be difficult to present the full production system. The result of LCA is not only used for the lower level of decision making but also for the higher level. Usually, aggregated data is preferred by the higher level decision makers. They, of course, want to have concise information about environmental load of products or processes as a whole rather than a detailed numerical value (KORTMAN et al., 1994).

These shortcomings can be resolved by applying the idea of heuristics.

4 Application of Heuristic Concepts

4.1 The concept of heuristics

Heuristics as a study is originated from the discipline of optimisation. The optimisation theory that begins with linear programming has developed into a more complex theory such as non-linear programming and integer programming. Thus, in spite of the recent breakthrough of such tools as computers, they still require much effort and time for finding an exact solution. The heuristic approach has been also discussed in the area of problem solving. Because of the complexity of problem and bounded rationality of humans, people adapt a selective search within a problem space, using heuristics to guide the search, even though they sometimes do not guarantee exactness.

However, the proper course of inquiry and action is not always readily apparent. In addition, an exact solution is rarely needed for applications in a real situation. Heuristics is a set of generic procedures which has been adopted for solving a optimisation problem. With this approach, it is possible to be free to determine the particulars of the situation and ascertain appropriate responses. The solver invokes his/her own skills of observation, inference, and general critical and creative thinking. This approach is more applicable and valuable to real world situations than rigid algorithmic approaches, since it is faster and provides a solution with acceptable or tolerable error.

4.2 How heuristics applies to LCA methodology?

Heuristics is a discipline using some kind of trial and error approach. However, the goal or the concept in this article is to show that the heuristic approach tries to find solutions which are nearly exact or exact by consuming significantly less cost and time. The heuristic approach is not a method but just an approach or a concept. It uses existing methods, more than the methods used in traditional LCA, for gathering operating data. It is therefore hard to describe or even hard to define the detail procedures for heuristic approaches.

Time required to find a solution is important in heuristics theory, and the term 'time' implies efforts or cost in a business situation. For some cases, it is inevitable to find an exact value regardless of cost, but no serious problems would generally rise with inexact values. Therefore, it does not contravene the original purposes of the LCA study. The idea of heuristics will be more valuable and preferred if cost and efforts can be reduced. For the other cases, the argument is what percentage of error can be tolerated. **Figure 2** is the relation of an accuracy of data and cost or efforts. It is the logistic-like curve. Major concerns are involved with the fact that the curve does not yet converge to exactness. An LCA practitioner should decide the accuracy with available cost.
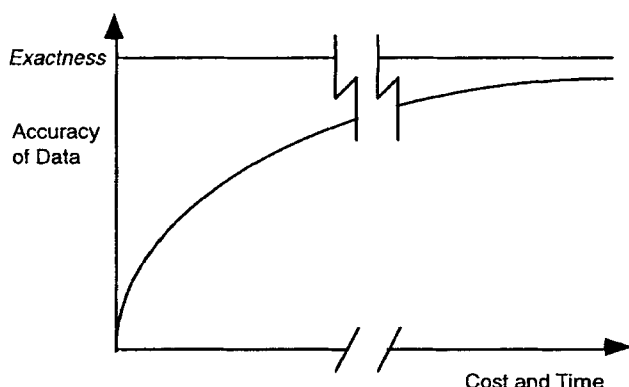

Fig. 2: The relation of cost and accuracy of data

In addition, it can only be applied to cases in which reasonable heuristic opinions possibly exist. The methodology should not be applied to the cases that have a possibility of error due to the intuition of an administrator or for those involving toxic materials, which are very sensitive to error.

5 Applicability of the Heuristic Approach to LCA

In the initiation phase, internal decision making and the public disclosure of information are proposed for the private sector, and the evaluation and establishment policies and public education for the public sector. An analysis for acceptability is partly based on those initiation purposes.
In general, it is the purpose of LCA to construct fundamental information about resource use, energy consumption, and environmental loading. There would be no serious problem

when including heuristic data to the LCA data set in sight of understanding overall framework, except that the implicit purpose is to use the symbolism and illusion of number. There are phenomena which demonstrate that the result seems more reliable and closer to 'truth' when the detail number is displayed. Regardless of this fact, the phenomena are evaluated as being desirable or not. Consequently, it seems to be cost ineffective to invest so much money to print a series of digits. Considering the collection of data, using the heuristic method is very desirable.
Extreme accuracy is also already neglected in a traditional LCA with uncertainties, which are well described by LINDFORS et al. (1995), and with assumptions. The subsequent issue is how much error can be accepted and tolerated. For example, there is a trend that one percent error is tolerated in transportation. In addition, Franklin Associates (1993) consider two systems to be different for a comparison of two products if there is at least a 10% difference in the total for energy and post-consumer solid waste by weight, and a 25% difference for post-consumer waste by volume, industrial solid waste, air pollution, and water pollution. Of course, serious consideration is taken for the case of small amount dependency, for example toxic material such as chlorofluorocarbon and uranium.

5.1 Class of LCA in which the heuristic approach can be applied

The class of LCA to which the heuristics concept can be applied is similar to that of simplified LCA. It would be applied effectively when LCA is carried out for a process that is not directly related with the purpose of analysis, especially for comparison of products or processes.
This approach cannot be used in every case. There are also many cases in which the heuristic approach cannot be used. However, this was not the case because of the fact that experts did not have data, but because of the characteristics of these cases. It can be used as a complementary method, too.

It would be more useful for a somewhere-to-grave case that contains a product chain rather than for a gate-to-gate case. For example, when transportation is a critical process for understanding the overall scope, it will be somewhat difficult to implement heuristic ideas without serious considerations. It would be less useful for the cases where transportation can be considered as a set instead of as several elements, or where transportation is a common identical process for several products.

5.2 Applicability – aspects of data quality

5.2.1 Quantitative DQIs

Quantitative DQIs are related with the spread or variability of the data set. They consist of precision represented mainly by average and variance along with completeness, homo-

geneity, correlation, uncertainty, and so forth. It can be argued that quantitative analysis cannot be made without direct measurement or using secondary data. However, quality assessment of heuristic data can also be accomplished through questionnaires to experts or the Delphi method. For some cases, the number of collected observations can be larger than that of direct measurement or secondary data acquisition, depending on the number of experts. It is more useful to follow an analysis.

5.2.2 Qualitative DQIs

All indicators, including quantitative ones, are used in evaluation after real analysis has been performed. In another viewpoint, pre-analysis evaluation for each indicator would be used for evaluating their goodness.

1. Consistency: Consistency is a measurement of how uniformly the research methodology is applied to the various components of the study. Application of this indicator for an heuristic approach has relatively little meaning, because it is not used in many processes and products in general. However, for the process and products to which the heuristic approach can be applied, consistency can be guaranteed more strictly because there are fewer difficulties of gathering data than through the traditional approach.

2. Applicability/Suitability: This indicator refers to the relevance of the data sets within an analysis to the stated purpose of the research. There is nothing problematic, since the heuristic method is already restricted and preconditioned for relevance.

3. Representativeness: This measure is normally judged by the comparison of values determined in the study to existing reported values in other analysis or published data sources. However, the application of an heuristic idea means that there is little reported data which exists. It is also possible to compare values from a different heuristic approach, and if there are any significant variances it can be examined and explained. Making new representative data by integrating several researches is also possible.

4. Identification of Anomalies/Missing Data: It would be difficult to find extreme values when the opinions of experts are used as data. In many studies it is reported that human beings demonstrate a tendency to of avoid an extreme value. In addition, using heuristic data contribute to a reduction in missing data, while of course it cannot eliminate the fundamental problem of lacking.

5. Reproducibility: Because it uses the opinions of experts and methodology from social science, it should be noted clearly that the category of persons who reproduce information can be different from that of the individual who has made it originally. In spite of the clear description, it is hardly expected that exactly the same result can be reproduced because of the human factor.

6. Accessibility/Availability: This indicator reflects the degree to which information regarding the study has been made available or accessed by either internal experts and/or external reviewers for examination of the methodology and data values. A couple of alternative methods such as Delphi can be used for heuristic approach. It can contain and integrate the opinions of experts and thereby makes those arguments meaningless.

5.3   Simplified LCA and the heuristic approach

As noted already, some shortcomings of simplified LCA can be resolved with the application of the heuristics concept. Organisations cannot use the result of screening LCA externally, as officially, because the data used are unofficial and not validated. However, the heuristic approach intends to use expectations or opinions of experts, and they can be used to replace what is unavoidable in typical inventory analysis. Thus, it is possible to give officiality to data through the responsible statements such as certification of internal or external experts, and it is ultimately possible to use this even officially.

On the other hand, typical streamlined LCA does not present the result of LCA as a whole, whereas the heuristic approach does. Moreover, a preceding analysis is required for streamlined LCA to determine critical processes, but the heuristic approach basically considers all processes as important so that a pre-analysis can even be needless. In pre-analysis, some important processes with critical impacts can be determined to be ignored because the impacts are not revealed. The heuristic approach can serve to preserve them.

6   An Example of Applying the Heuristic Approach – Transportation

Transportation from a unit process to another can be a good example of the heuristic approach. **Figure 3** is a part of the example flow diagram. Each arrow means transportation. The difference of arrow thickness means that the characteristics of the arrow are different, i.e. only a thick arrow is pure transportation, and distribution consists of a proportion of storage and transportation. However, the issue of the difference of transportation and distribution is beyond the scope of this paper.

In fact, much data for transportation is difficult to be exact. Trucking, train, air, shipping, and pipeline are the major transportation options. For trucking, an exact calculation of the amount of gas and oil, and subsequent emissions requires information on the size of the truck, standard efficiency of fuels, and driving mode. To obtain the data, secondary data of road management office or the primary data from real measurements are needed. For some cases, the amount of oil and gas is measured directly. However, it is trivial that the transportation distance cannot be identical
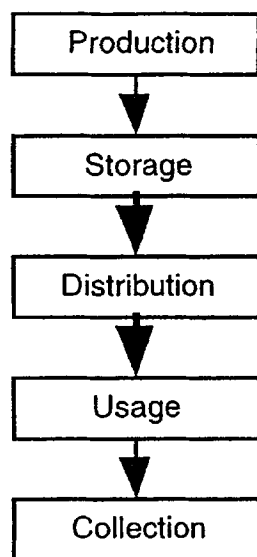
Fig. 3: An example of flow diagram

for any case. There is a sample size problem and variance problem in repetitious measurement. Though it is tolerable to take errors, it is difficult to manage and maintain the continuous change of transportation network. The measures would already be invalid when they attempt to apply them to analysis. To avoid it, unreasonable assumptions should occasionally be set up.

It is similar to the case of air traffic and shipping. In the case of trains, the transportation distance only for trains can be obtained relatively accurately, but there are little cases where only trains alone are used during the whole transportation process. Pipeline is most analysable because the measurement of transportation distance is relatively easy and additional transportation methods are not used for many cases, although it is available only for case of fluids.

With the heuristic approach, estimated data on distribution distance and fuel consumption can be obtained by several ways. They include questionnaires to the truck drivers. The experts in the environmental science can provide accompanying CO_2 and other emissions.

This methodology can also be applied to the rough estimation of unknown environmental impacts of a material. For example, one can assume that the environmental impacts from applying one kilogramme of lead-based paint has about the same impact as one and half of same amount of lead ion (KIM, 1996).

7 Summary and Conclusion

Estimation is a very important procedure as we agree. Statements about estimation have been appeared in many studies. However, those statements seemed to be too basic and

elementary. More systematic analysis is required for completeness of estimation methodology. This paper can be one of them. The heuristic approach is more reliable than other approaches that use quantitative data with already recognised errors or already known improperness, and with significant cost. Application of heuristics for these cases can lead the trade-off relation of accuracy and cost to a more desirable alternative.

In addition, the heuristic approach can contribute partially to the affluence of LCA results. SCHLEICHER (1996) discussed that the limited practical experiences with conducting LCAs have raised more questions than they have answered. Many LCA results using the heuristic approach will help the extended development of general LCA methodology. It should not be ignored that large number of heuristic opinions are launched by internal experts and they can show the tendency that place their company's products in a favourable light. As SCHLEICHER (1996) mentioned, LCAs obviously no longer help in decision making in such situations. Some sort of validation process will be required.

Uncertainty of data is difficult to solve, but future research should be directed to that area. Emphasis of heuristics and expert opinion can be one of the approaches.

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